

CTPH-P02-004

Application No.: 09/584881

Filing Date: 01 June 2000

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9594151

IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

In re Patent Application of:

Docket No.: CTPH-P02-004
(PATENT)

Hagood et al.

Application No.: 09/584881

Confirmation No.: 4595

Filed: June 1, 2000

Art Unit: 2834

For: ELECTRICAL POWER EXTRACTION
FROM MECHANICAL DISTURBANCES

Examiner: Dougherty, Thomas M.

DECLARATION UNDER 37 C.F.R. §1.131

Mail Stop Amendment
Commissioner for Patents
P.O. Box 1450
Alexandria, VA 22313-1450

Sir:

I, Nesbitt W. Hagood IV, state that I am a named inventor of the patent application identified above (herein referred to as the "Hagood Application") and am an inventor of the subject matter described and claimed therein. I understand that the Examiner has rejected certain claims of the Hagood Application in view of the U.S. Patent 6,486,589 to Dujari et al. (herein referred to as the "Dujari Patent") and having an effective filing date of 3 May 2000.

The claims of the Hagood Application, as presently amended, are directed to, inter alia, a system and method for at least partially suppressing a vibration of a mechanical disturbance using an electromechanical transducer coupled to the disturbance. An electrical circuit having at least one active switch is in communication with a sensor and is coupled to the transducer for causing the transducer to act on the disturbance to at least partially suppress the vibration, based on a characteristic of the disturbance measured by the sensor.

As evidenced, inter alia, by the exhibits attached hereto, I and the other co-inventors had possession of the claimed invention before the 3 May 2000 effective filing date of the Dujari Patent. In particular, the Hagood Application claims the benefit of U.S. provisional patent application 60/158,538, filed on 8 October 1999 and titled "Electrical Power Extraction from Mechanical Disturbances" (herein referred to as the "Hagood Provisional") and is also a continuation-in-part of U.S. patent application 09/323,739 (now U.S. Patent 6,580,177), filed on 1 June 1999 and titled "Electrical Power Extraction from Mechanical Disturbances" (herein referred to as the "Hagood Patent"). I am a named inventor of the Hagood Provisional and the Hagood Patent, and the claimed subject matter was disclosed in the Hagood Provisional and the Hagood Patent.

Exhibit A includes excerpts from the Hagood Patent demonstrating certain aspects of the claimed subject matter having to do with, for example, a transducer being used to extract energy from a disturbance and also to suppress a vibration of the disturbance; a sensor being used to measure a characteristic associated with the disturbance; various sensor types and characteristics that they can measure; and phase matching and/or motion matching to extract more energy from the disturbance.

Exhibit B includes excerpts from the Hagood Patent demonstrating certain embodiments of the energy extraction and vibration damping systems and methods. Although only Figs. 1B and 5 have been referred to in **Exhibit B**, it should be understood that other embodiments, such as those shown in, for example, Figs. 7, 8, 9, and 10A of the Hagood Patent (not cited herein) also demonstrate possession of the claimed subject matter of the Hagood Application.

Exhibit C includes references to Figs. 25–27 and corresponding descriptions in the specification of the Hagood Provisional, demonstrating, inter alia, possession of the claimed subject matter of the vibration suppression systems and methods.

Exhibit D cites Fig. 23 of the Hagood Provisional (and corresponding description in the specification) as well as a relevant excerpt from the specification of the Hagood Patent,

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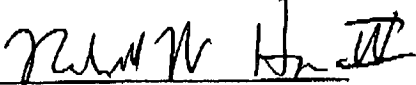
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demonstrating, inter alia, possession of the subject matter claimed in the Hagood Application related to self-powered systems and methods.

Exhibit E cites Fig. 24 of the Hagood Provisional and corresponding excerpts from the description thereof, demonstrating possession of the subject matter claimed in the Hagood Application related to use of rectifier circuits. Fig. 24 shows coupling of rectifier 571 with the transducer 570.

All exhibits attached hereto are extracted from at least one of the Hagood Provisional and the Hagood Patent, and therefore demonstrate that I and the other co-inventors of the Hagood Application were in possession of the claimed subject matter before the 3 May 2000 effective filing date of the Dujari Patent.

The undersigned declares further that all statements made herein of his own knowledge are true and all statements made on information and beliefs are believed to be true; and further that these statements are made with the knowledge that willful false statements and the like so made are punishable by fine or imprisonment, or both, under Section 1001 of Title 18 of the United States Code and that such willful false statements may jeopardize the validity of the application of any patent issuing thereon.


Nesbitt W. Hagood IV

Date: 11-28-04

EXHIBIT A

Hagood Patent, p. 2, lines 3–14:

Electrical power extracted from, for example, a vibrating structure such as a tennis racket (or any other sporting equipment), can be used to self-power the transducer and supporting electronics for use of the transducer as a vibration suppression actuator, or to power sensors on the sporting equipment or other special effects. Power extracted from, for example, machinery motion, can be used to self-power the transducer for use as a vibration suppression actuator or to provide power for a remote sensor and wireless telemetry in, for example, condition based maintenance of machinery and structures.

Hagood Patent, p. 2, line 32 to p. 3, line 6:

A system state is monitored and the switches are controlled based on the system state. The duty cycle of the switches is controlled.

Coupling the electrical circuit can act to increase oscillations of the disturbance. Alternatively, coupling the electrical circuit can act to dampen oscillations of the disturbance.

Hagood Patent, p. 11, line 32 to p. 12, line 24:

By applying a voltage to transducer 12 having an appropriate amplitude and phasing relative to disturbance 14, transducer 12 will undergo more mechanical deflection under the load than would otherwise occur. Thus, more work is done on transducer 12 by disturbance 14 and more energy can be extracted by circuit 10.

The duty cycle of MOSFETs 32, 34 is controlled by measuring the motion of disturbance 14 and selecting a time-varying duty cycle to match the motion of disturbance 14. This provides for effective power extraction over a wide frequency

range of the disturbance. Control logic 18 includes a sensor 40, for example, a strain gage, micropressure sensor, PVDF film, accelerometer, or active fiber composite sensor, which measures the motion or some other property of disturbance 14, and a control electronics 44. Sensor 40 supplies a sensor signal 42 (FIG. 1B) to control electronics 44 which drive MOSFETs 32, 34 of switching amplifier 16. System states which sensor 40 can measure include, for example, vibration amplitude, vibration mode, physical strain, position, displacement, electrical or mechanical states such as force, pressure, voltage or current, and any combination thereof or rate of change of these, as well as temperature, humidity, altitude, or air speed orientation. In general any physically measurable quantity which corresponds to a mechanical or electrical property of the system.

EXHIBIT B

Hagood Patent, p. 8, line 31 to p. 9, line 9 (Excerpt of Description of FIG. 1B):

Referring to FIG. 1B, a switching amplifier 16 includes switches, for example, MOSFETs 32, 34, ZGBTs, or SCRs, arranged in a half bridge, and diodes 36, 38. (Alternatively the switches can be bidirectional with no diodes.) MOSFETs 32, 34 are switched on and off at high frequencies of, for example, about 100 kHz. Switching amplifier 16 connects to transducer 12 through an inductor 30. The value of inductor 30 is selected such that inductor 30 is tuned below the high frequency switching of MOSFETs 32, 34 and above the highest frequency of importance in the energy of disturbance 14 with inductor 30 acting to filter the high frequency switching signals of circuit 16.

Hagood Patent, p. 13, line 31 to p. 15, line 7 (Description of FIG. 5):

FIG. 5 shows the flow of power between disturbance 14 and storage element 20, and the flow of information (dashed lines). The power from mechanical disturbance 14 is transferred to transducer 12 which converts the mechanical power to electrical power. The power from transducer 12 is transferred to storage element 20 through switching amplifier 16. Power can also flow from storage element 20 to transducer 12 through switching amplifier 16. Transducer 12 can then convert any received electrical power to mechanical power which in turn acts upon a structure 50 (FIG. 6) creating disturbance 14. The net power flows to storage element 20.

The power for sensor 40 and control electronics 44 as well as the cyclic peak power needed by transducer 12 is supplied by the energy accumulated in storage element 20, which has been extracted from disturbance 14. Energy accumulated in storage element 20 can also or alternatively be used to power an external application 48 or the power extraction circuitry itself for vibration suppression.

Losses in the system include losses in energy conversion by transducer 12, losses due to voltage drops at diodes 36, 38 and MOSFETs 32, 34, switching losses, and losses due to parasitic resistances or capacitances through circuit 10.

The control methods or processes can vary dependent upon whether maximum power generation is desired or self-powering of a transducer acting as a vibration damping actuator is desired. When maximum power generation is desired a feedback control loop uses the signal from sensor 40 to direct MOSFETs 32, 34 to apply a voltage to transducer 12 which acts to increase the mechanical work on transducer 12 contracting and expanding transducer 12 in phase with disturbance 14 essentially softening transducer 12 to disturbance 14. More energy is extracted from disturbance 14, however vibration of the structure 50 (FIG. 6) creating disturbance 14 may be increased.

When transducer 20¹ is being used to dampen vibration of mechanical disturbance 14, a feedback control loop uses the signal from sensor 40 to adjust the duty cycle of MOSFETs 32, 34 to apply a voltage to transducer 12 which will act to damp the vibrations. The system provides self-powered vibration dampening in that power generated by transducer 12 is used to power transducer 12 for dampening.

¹ The correct reference is transducer 12.

The diagram shows a control system architecture. At the top is a block labeled 'MECHANICAL DISTURBANCE' (14). Below it is a 'TRANSDUCER' (12), connected to the disturbance block by a bidirectional arrow. Below the transducer is a 'SWITCHING AMPLIFIER' (16), also connected by a bidirectional arrow. Below the amplifier is a 'STORAGE' block (20), connected by a bidirectional arrow. To the left of the storage block is an 'EXTERNAL POWER APPLICATION' block (48), connected to the storage block by a bidirectional arrow. To the right of the storage block is a 'CONTROL ELECTRONICS' block (44), connected to the storage block by a solid line. To the right of the control electronics is a 'SENSOR' block (40), connected to the control electronics by a dashed line. The sensor block is also connected to the storage block by a solid line.

FIG. 5

EXHIBIT C

Hagood Provisional, p. 29, line 25 to p. 30, line 17:

Referring to Fig. 25, a circuit 510 for dampening vibration of a structure to which a transducer 511 is attached includes an energy dissipation component 513, such as a resistor, in the circuit. Circuit 10 also includes an inductor 512 and two symmetric sub-circuits 514a, 514b. Each sub-circuit 514a, 514b includes a diode 516a, 516b, a switching element 517a, 517b, and control circuitry 518a, 518b, respectively. The switching element 517a, 517b is, for example, a MOSFET, ZGBT, or SCR. The dissipation element 513 can be eliminated if the inherent energy loss in the remaining circuit components provide sufficient energy dissipation.

Fig. 26 shows an implementation of the circuit of Fig. 25 incorporating the self-powered control circuitry 549a, 549b described above with reference to Fig. 23.

Referring to Fig. 27, a circuit 520 for dampening vibration of a structure to which a transducer 521 is attached includes an inductor 522, an energy dissipation component 523, such as a resistor, and two symmetric sub-circuits 524a, 524b. Each sub-circuit 524a, 524b includes a diode 525a, 525b, a switching element 526a, 526b, and control circuitry 527a, 527b, respectively. The switching element 516a², 526b is, for example, a MOSFET, ZGBT, or SCR. The dissipation component 523 can be eliminated if the inherent energy loss in the remaining circuit components provide sufficient energy dissipation.

² The correct reference is 526a.

Hagood Provisional, Figs. 25-27:

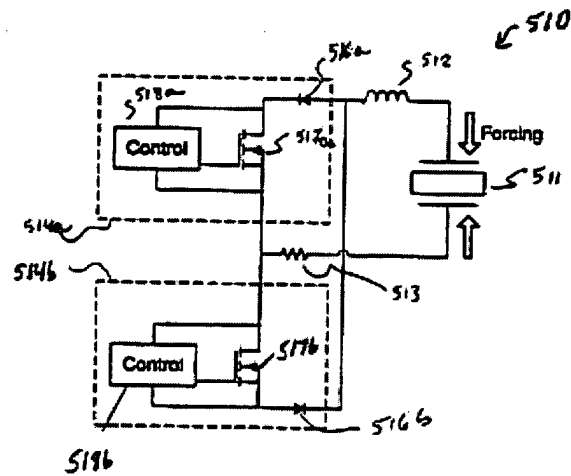


Fig. 25

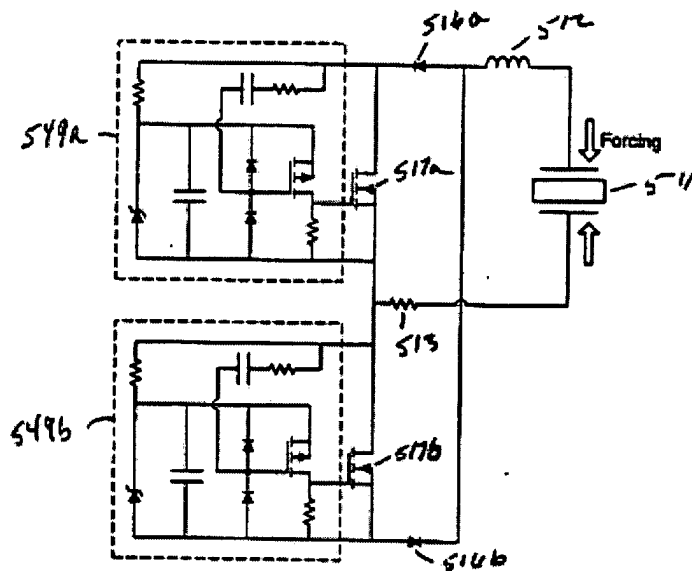


Fig. 26

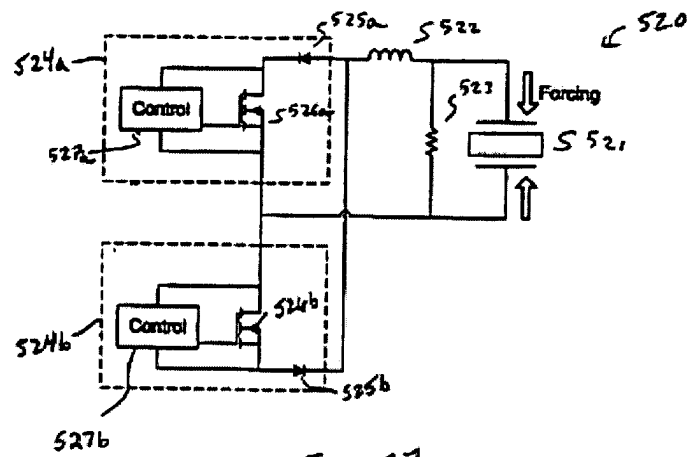


Fig. 27

EXHIBIT D

Hagood Patent, p. 21, line 31 to p. 22, line 5:

The power for sensor 40 and control electronics 44 as well as the cyclic peak power needed by transducer 12 is supplied by the energy accumulated in storage element 20, which has been extracted from disturbance 14. Energy accumulated in storage element 20 can also or alternatively be used to power an external application 48 or the power extraction circuitry itself for vibration suppression.

Hagood Provisional, p. 28, line 30 to p. 29, line 12 (Description of Fig. 23):

Referring to Fig. 23, a self-powered circuit 550 for extracting electrical power from transducer 501 requires no external power for operating control circuits 549a, 549b and transducer 501. A capacitor 551, which is charged up through a resistor 552 and/or through resistor 554, capacitor 555 and diode 557 during Phase I of the circuits operation (i.e. while the voltage across the transducer is increasing), acts as the storage element. A zener diode 553 prevents the voltage of capacitor 551 from exceeding desired limits. When the voltage across transducer 501 begins to decrease, a filter (resistor 554 and capacitor 555) turns on a p-channel MOSFET 556. MOSFET 556 then turns on switch 506a, using the energy stored in capacitor 551 to power the gate of MOSFET 556. In the process, capacitor 551 is discharged, causing switch 506a to turn off after a desired interval. The same process is then repeated in the second half of the circuit.

Hagood Provisional, Fig. 23:

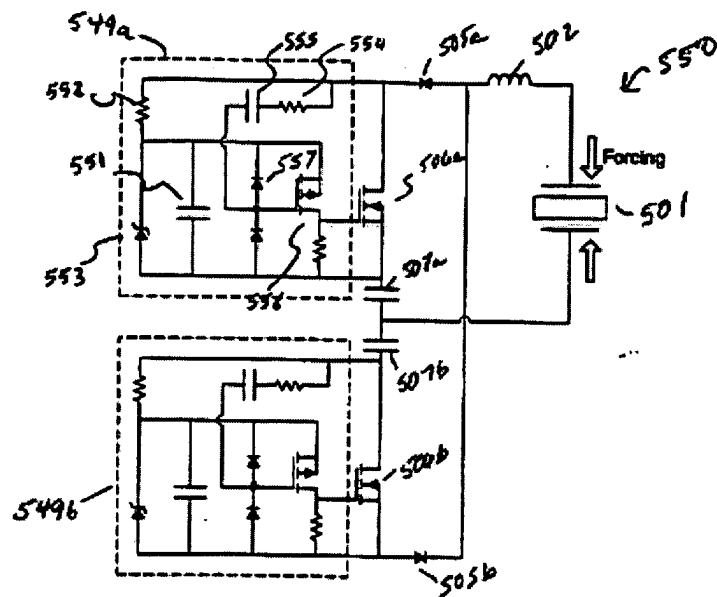


Fig. 23

EXHIBIT E

Hagood Provisional, p. 29, lines 13–16 and lines 22–24:

Referring to Fig. 24, a circuit 569 for extracting electrical power from a transducer 570 includes a rectifier 571, an inductor 572, a switching element 573, a storage element 574, and control circuitry 575.

Circuit 569 can also be used to dampen vibration of a structure, for example, vibrating machinery or sporting good.

Hagood Provisional, Fig. 24:

